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CONTENTS

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EDITORIAL

The policy of the **Journal of Applied Science in Southern Africa, (JASSA)**, is to publish six to ten original research papers, plus a review type of paper and a book review (when available), per issue.

In this volume 2, issue 2, seven original research papers and a book review are published. At the risk of being repetitive and perhaps redundant, it is important though to remind readers that JASSA is an international and refereed journal and quoted in a number of citations. Its is published by the University of Zimbabwe Publications Department two times a year.

In this issue the international nature of the journal policy is stressed by contributions, not only from Zimbabwe, but also from the Southern Africa Development community (SADC) region and Europe (United Kingdom). This is an important aspect of the intention of the journal, i.e. the regional and international exchange and dispension of applied research sciences findings in Southern Africa. It is hoped that future issues will maintain this all important trend.

Once more, the diversity of the applied science nature of the papers presented in this issue has been maintained. The papers impact on the areas of ecology and the environment, (Ecological degradation in cities: impact of urban agriculture in Harare, Zimbabwe); soil sciences, (Soil pH and lime requirement for high potential communal areas of Zimbabwe); plant pathology, (Laboratory screening of metarhizium flavoride and Beauveria bassiana for control of mecostibus pinivorus, a Pinus patuladefoliator in Zimbabwe); mathematics, (Computer extended series for pipe flow: Effect of viscosity variation due to temperature); physics, (The role of geometry in low energy photon attenuation experiments) and horticulture, (Dynamics of mushroom, *Boletus edulis* production in pine plantations in Zimbabwe).

The book reviewed in this issue is *Smallholder Horticulture in Zimbabwe*. This book review highlights the importance of horticulture in the areas of crop production, resource use and environmental sustainability, marketing and transport and sociological and gender issues. The book is the first of its kind in highlighting the importance of integrating all aspects of smallholder horticulture in the region. Questions raised in this book should provide direction for more research in the field of smallholder horticulture.

Lastly, JASSA welcomes comments from its valued readers.

C. F. B. Nhachi
Editor-in-Chief

Ecological degradation in cities: Impact of urban agriculture in Harare, Zimbabwe

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Abstract

The effect of the increasingly widespread practice of urban agriculture in the City of Harare on the natural biodiversity was investigated. Vegetation surveys noting species presence-absence and abundance were undertaken in seven field areas, identifying the components of the natural vegetation of both the clay soil-type areas developed on basic rock, and the sandy soil-type areas developed on granite, that typify the city. Change brought about by the increasingly widespread practice of urban agriculture was determined, and knock-on effects for other aspects of the city's ecology were investigated. Most open space areas in Harare are vlei land. Detrended Correspondence Analysis (DCA) illustrated significant differences in the species composition of uncultivated vlei areas with distance from the vlei channel, reflecting change in the waterlogging conditions of the soil. A higher diversity of faunal species, and larger species count, prior to cultivation was also noted. The effects of cultivation on the vegetation were a change in species composition (with the natural vegetation being replaced by mainly alien arable weeds), the loss of the spatial diversity in species presence and dominance, a significantly reduced ground cover, and a loss of habitat diversity. The implications of these changes for the amenity value of the city environment is discussed. The need for a more sensitive management of open-land areas within Harare, while the possibility of their conservation as areas of viable natural ecological diversity is still available, is highlighted.

Key words: Biodiversity, city environment, urban agriculture, vlei land, amenity value, ecological conservation

Introduction

Vlei ecology in Harare

Vleis exist as seasonally waterlogged drainage ways. In Harare two main types occur: clay vleis developed on basic rocks, which are mostly found in the northern half of Harare (largely the Gwebi, Umwindsi and the upper headwaters of the Marimba and Mukuvisi areas), and sandy vleis occurring on Granites mostly in the southern half of Harare (largely the Jaoha and the major portions of the Mukuvisi, Figure 1). During a good rainy season (generally October to March in Harare), both these types of vlei become thoroughly waterlogged (the water table having risen to the surface). As such, the vleis resemble linear marshes stretching radially from the city centre. In the wet season they are an obstacle to free movement. The self-mulching action of the vlei soils (capable of considerable expansion on wetting and shrinkage on drying exhibiting waterlogging in the wet season and marked desiccation cracking in the dry season; Thompson, 1972), require specialised foundations for urban development to avoid structural damage to roads, sewers, and buildings (Tomlinson and Wurzel, 1977). Although technically feasible, the sound development of these areas is costly. As a result, the vleis have been largely avoided for development, and as such, they clearly define a sectoral structure to the city (sectors of development separated by vacant vlei land). Also as such they have become a favoured characteristic of Harare's urban

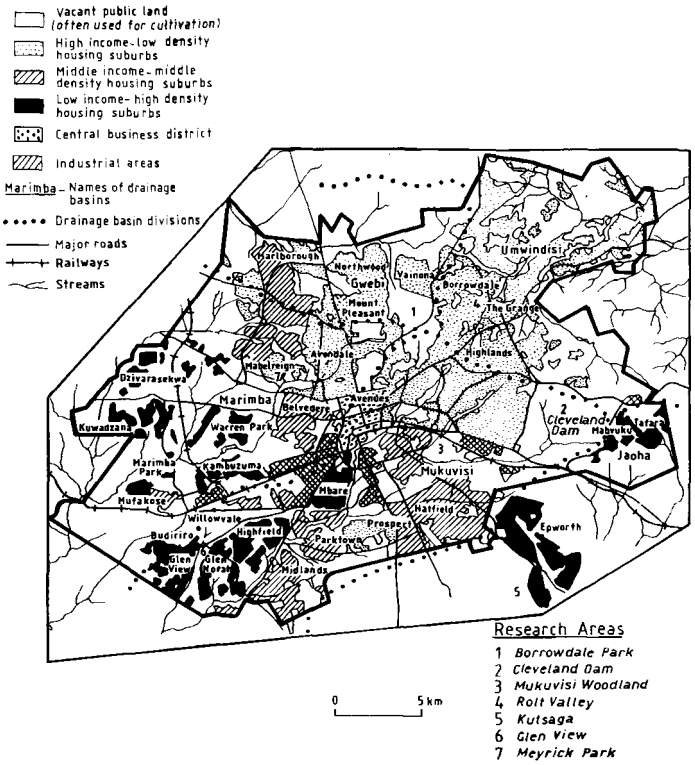

Figure 1: Harare's urban structure indicating vlei land and location of research sites

structure: being the green open spaces used as parkland or for recreation.

A good example of open-space vlei land in Harare is Borrowdale Park. This is situated between the low-density suburbs of Groombridge, Vainona and Northwood laid out in the 1950s and early 1960s (Figure 1), on former agricultural land to the north of the city centre. It is the headwater and vlei drainage area contributing to the Gwebi River to the north of the city. Residents in the Borrowdale Park area of Harare, from the 1950s, 60s and 70s recall the Borrowdale vlei flowing as a stream for much of the year. Fed by the rains during the wet season, it diminished into pools only towards the end of the dry season. In these crabs and fish such as barbel could be found. Because of the varied hydrology of vleis, both spatially and annually, and because of their favourable potential productivity in terms of them being morphological wetlands in otherwise climatic drylands, vleis provide significant ecological interest to the areas where they occur. They are known for their species abundance and diversity.

A botanical survey undertaken in the early 1980s in a drier part of the Borrowdale Park vlei recorded over 320 species of flowering plants, and it is likely that the total number in the whole of Borrowdale Park would be between 400 and 500 species. These species support a wide diversity of insect life and, until recently, larger fauna also made their home here. Notably this included a viable population of steenbok, duiker, jackal, antbear, and scrub hare, with occasional sighting of reedbuck, serval and wild cat. The vlei was home to a large rodent population, including giant rats, cane rats, mole rats, and other smaller rodents. Snakes included cobra and python. Birds included

nightjars, owls, black-shouldered kites, plovers, wheatears, herons and hammerkops; also secretary birds.

The considerable aesthetic and recreational value provided by such areas to an urban population has been recognised and highly prized since town planning became a discipline (Adams, 1932; Abercrombie, 1959). Such areas are accepted as significant in maintaining the vitality and viability of urban life (GOZ, 1977; Muedziwa, 1990). More recently, the world-wide drive towards sustainability, following the 1992 Rio Summit, has highlighted the importance of biological diversity in city regions (Breheny, 1993).

Ecological change

Because of the increasing demands of the rapidly expanding population of Harare (increased from 658,900 in 1982, to 1,4 million in 1992; CSO, 1994), the vacant land of the vlei areas are an increasing focus for development, including for housing, commerce and industry. Two vlei sites recently pegged for such development include a stretch of the Mukuvisi just south of the city centre between the high-density low-income suburbs of Mbare, Ardbennie and Sunningdale; and a tributary of the Mukuvisi between the Willowvale Industrial Site and the high-density low-income suburbs of Glen View and Glen Norah (Figure 1). Such development is helped by the apparently natural progressive drying of Harare's vleis, observed throughout the city during approximately the last 15 years. Nowadays within Harare, besides occasional floods of urban storm runoff, waterlogging of significant areas of vlei land for significant periods of time during the rainy season, is less common. These hydrological changes are the subject of a further paper in preparation by the authors. Potential implications for vegetation change only will be outlined further here.

The vegetation of the vleis is sensitive to changes to the hydrological regime. The number and abundance of species favouring wetter vlei conditions will be decreasing, while the number and abundance of species favouring dryer vlei conditions will be growing. This has implications for the insect, birdlife and other fauna. Concomitant with the effects of apparent desiccation, however, is also a significant increase in the occurrence of cultivation.

Urban agriculture

In rural Zimbabwe, vleis have long been favoured areas for cultivation, not least because they are the first areas to collect and hold water at the onset of the rains (permitting an early crop). They also retain water well into the following dry season (also permitting a late crop, Rattray *et al.*, 1953; Theisen, 1975; Whitlow, 1983). From the 1950s, however, efforts have been made through the implementation of Streambank Protection Regulations of the Natural Resources Act (originally enacted in 1952) to forbid agriculture within 30 m of any wetland or watercourse. These regulations were developed largely as a measure to help reduce severe soil erosion, recognised as early as the 1930s as being a most severe threat to sustaining the country's development (McIlwaine, 1939). The very large sediment load of rivers throughout the country is an illustration of the severe land erosion problem in Zimbabwe. This was thought to be largely brought about by inappropriate disturbance of the soil, particularly along the watercourses.

Notwithstanding a well established City Council in Harare with a reputation for strong control over land use and development within the city in both pre-colonial and post-colonial times (refer for examples to Zinyama *et al.*, 1993), the unlawful cultivation of crops by city residents in the vacant open spaces of the city has been a recurring problem to the City Council. This began as early as the 1950s. Interpretation of aerial photography determined an average increase in the activity by 20 %per annum between 1955 and 1980 (Mazambani, 1982; Table 1). The majority of this cultivation is on vlei land (estimated to be 67% of the area of cultivation in 1994), and thus subject to control under the Streambank

Protection Regulations of the Natural Resources Act (Ch 246). It is also widely practised on road-side verges, land bordering railway track, government reserve land (for example, that identified for housing development), and vacant stands. Non-vlei cultivation is subject to control under the Harare (Protection of Lands) By-Laws of the 1973 Urban Council's Act (prohibiting the growing of crops without permission, and making provision for unauthorised crops to be destroyed), established to help the City Council fulfil its obligations under the Natural Resources Act.

The cultivation is almost entirely for subsistence foods (mostly maize, and sweet potatoes) by city residents purportedly finding it difficult to support themselves on household income (AAD A/45/7: 21/4/76; 20/8/76; Mazambani, 1982; Bowyer-Bower, 1996a), and occurs throughout Harare (i.e. in both high-density low income areas, as well as low-density high-income areas; Bowyer-Bower, 1996a). Attempts have repeatedly been made to control cultivation in the name of environmental protection, by various governmental and municipal departments through the decades. This was particularly so during the latter part of the 1970s, following the establishment of the Harare (Protection of Lands) By-Laws, and with yet stronger efforts in the 1980s (Bowyer-Bower, 1995a; Mbiba, 1994). To this end an aerial photograph survey of the extent of cultivation on public land within Harare in 1990 (ENDA, 1994) determined little increase in the total area under cultivation compared to 1980 (Table 1). Press articles throughout the decade illustrated a continued sequence of events of Figure 2 (Bowyer-Bower, 1995a), which suggested the figures of Table 1 mask a cyclical pattern of a constant flux of areas coming into cultivation, while other areas are being abandoned.

Because of the unpopularity of the City Council's attempts at control, particularly during the severe drought of 1992, the activity has been largely allowed to continue unchecked since 1993. An aerial photograph survey of the extent of the cultivation activities during the 1993-94 rainy season (ENDA, 1994) indicated a doubling of the area of land used compared to the 1989-90 rainy season (Table 1). The subsequent 1994-

Table 1: Extent of area of cultivated public land in Harare, determined by survey of aerial photograph coverage

Year of Aerial Photograph Coverage	Area of Public land Cultivated (Hectares)	% of Total land Area of Harare[c] That is Cultivated	% of Open Space Area of Harare[d] That is Cultivated
1955	267[a]	0,5%	1,0%
1965	1066[a]	1,9%	4,0%
1972	1399[a]	2,5%	5,5%
1978	3696[a]	6,6%	14,0%
1980	4762[a]	8,5%	18,5%
1990	4822[b]	8,6%	26,9%
1994	9288[b]	16,6%	33,50%**

(Determined by Survey of Aerial Photograph Coverage.)

a: Information obtained from Mazambani 1982.
b: Information derived from ENDA 1994.
c: 55,900ha (land area of the Harare Municipality determined from 198 Surveyor General 1:33, 333 Map of Harare: Government Printer, Harare).
d: 41% of the total area of the Harare Municipality (determined from 1989 Surveyor General 1:33, 333 Map of Harare: Government Printer, Harare).
**: Estimated 57% of this cultivated area is vlei land.

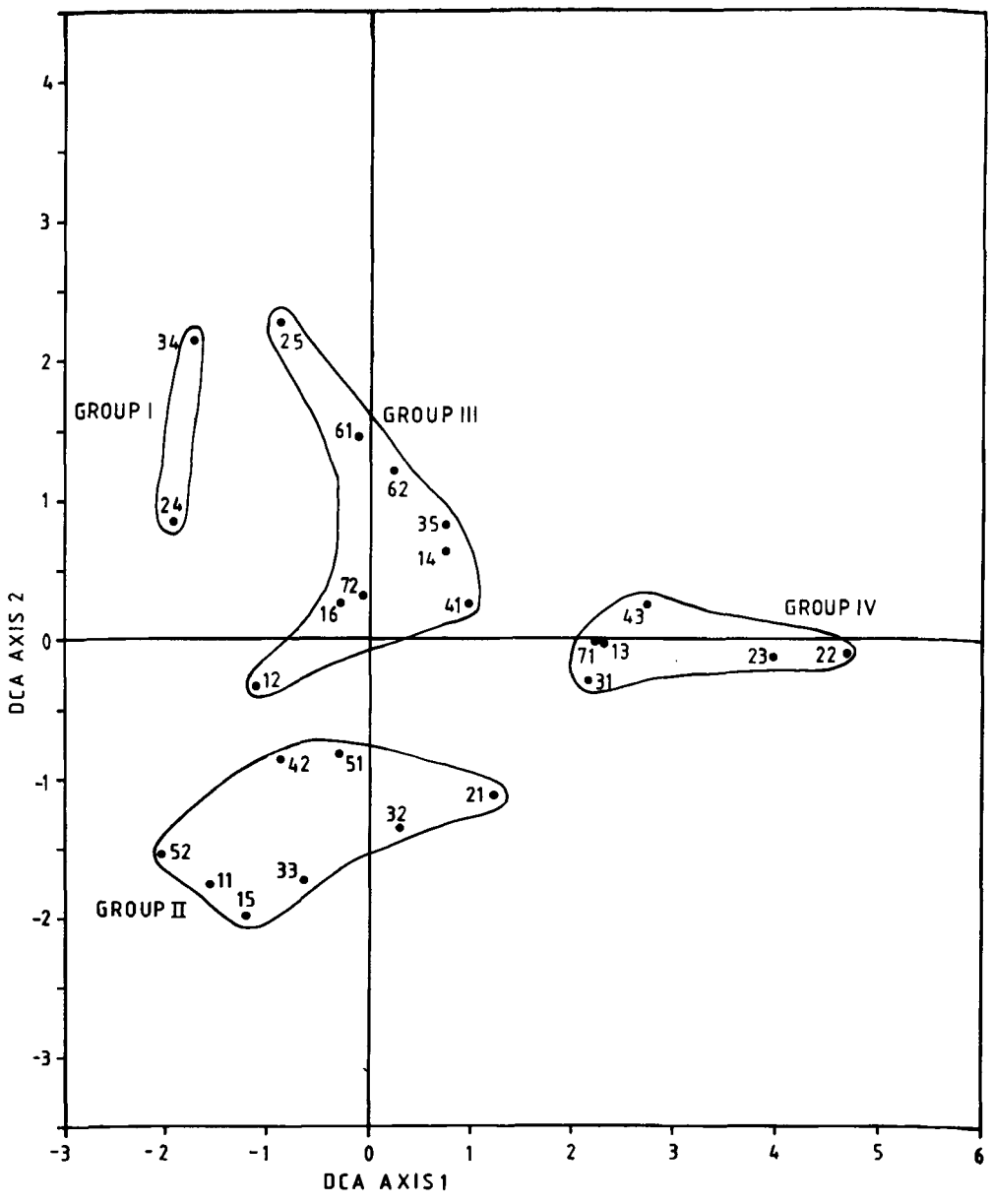

Figure 2: DCA ordination diagram Indicating degree of correspondence in species present at sample sites in Research areas in Harare

95 rainy season showed an even larger area of vacant public land in Harare under cultivation (personal observation of almost no area of undeveloped land within Harare being without cultivation: Bowyer-Bower, 1995) following an announcement by the City Council, in the lead up to the General Election in April 1995, that destruction of

unauthorised cultivation by the City Council was halted for the time being (*The Herald* 6/1/95).

The merits of the authorities giving way to public pressure to allow uncontrolled cultivation activities throughout Harare cannot be understood without a clear knowledge of the various impacts these cultivation activities have. The vegetation survey that is the subject of the rest of this paper, is a part of a wider study that has been undertaken in Harare during 1994 and 1995 to determine the environmental consequences of unlawful urban agriculture in Harare, Zimbabwe. Plant species presence-absence and abundance is determined on cultivated and uncultivated areas of the two main vlei types within Harare, from which the impacts of cultivation on the natural ecology are inferred. It is intended that the findings of this research can be used to help advise policy development that will help to ensure optimal and sustainable use of the city environment.

Research methodology

Only in vlei areas subject to more constant flow (for example, as brought about either by a considerable catchment area and/or in higher but strongly seasonal rainfall areas) is a discernible channel visible in the vlei centre. Vlei channels are more often manifest only in the wet season, as the first areas to become waterlogged, and with sufficient rainfall, the first area to exhibit water flow. The soil of the most waterlogged area of the vlei is strongly hydromorphic, with a sequence of change in soil condition with increasing distance from the vlei channel (less hydromorphism), where the soils also show more influence of

Tables 2a–2d: Dominant species composition for each of the four main Hydrological zones within uncultivated areas of the two main vlei types of Harare.

Table 2a: Zone A: Vlie Channel

Clay vlei		Sandy vlei
Grasses	**Herbs**	**Grasses**
Panicum trichonode	Senecio inornatus	Hemarthria altissima
Eulalia aurea	Alysicarpus zeyheri	Schoenoplectus corymbosus
Cymbopogon caesius	Chlorophytum silvaticum	
Hemarthria altissima	Commelina ceciliae	**Herbs**
Eragrostis capensis	Ipomoea lapathifolia	Senecio strictifolius
Leersia hexandra	Verbena bonariensis	
Sorghastrum nudipes	Eriosema nutans	
Paspalum scrobiculatum	Senecio strictifolius	

Table 2b: Zone B: Area adjacent to vlei channel most frequently seasonally waterlogged

Clay vlei		Sandy vlei
Grasses	**Broad-leaf herbs**	**Grasses**
Brachiaria humidicola	Gerbera ambigua	Arundinella nepalensis
Hyparrhenia nyassae	Vernonia glabra	Hyparrhenia rufa
Loudetia simplex	Oldenlandia herbacea	Paspalum scrobiculatum
Eragrostis capensis		Digitaria monodactyla
Eragrostis hierniana		Pennisetum macrurum
Imperata cylindrica		

Table 2c: Zone C: Dry areas further from the vlei channel and sometimes affected by fire

		Clay vlei		Sandy vlei
Grasses	***Small woody geophytes***	***Broad-leaved herbs***	***Broad-leaved perentals***	***Broad-leaved herbs***
Hyparrhenia filipendula	Acalypha peduncularis	Tephrosia decora	Acalypha peduncularis	Aspilia pluriseta
Themeda triandra	Scabiosa columbaria	Syzygium guineense subsp. huillense	Astripomoea malvacea	Becium angustifolium
Hyparrhenia rufa	Vernonia oligocephala	Justicia elegantula	Convolvulus sagittatus	Eriospermum abyssinicum
Loudetia simplex	Becium angustifolium	Eriosema shirense	Helichrysum nudifolium	
Cynodon dactylon	Becium obovatum	Acanthospermum australe	Eriosema ramosum	***Grasses***
Hemarthria altissima	Gnidia micrceophala	Dicerocaryum senecioides	Eriosema nutans	Loudetia simplex
Eulalia aurea	Justicia elegantula	Acacia sieberiana	Launaea nana	Aristida junciformis
Cymbopogon caesius				Hyparrhenia filipendula

Table 2d: Zone D: Where woodland begins on the outer edges of the vleis

	Clay vlei		***Sandy vlei***
Trees	***Shrubs***	***Grasses***	**Trees (miombo woodland)**
Bauhinia thonningii	Vangueriopsis lanciflora	Digitaria milanjiana	Brachystegia spiciformis
Julbernardia globiflora	Dolichos kilimandscharicus		
	Diospyros lycioides		***Shrubs***
	Aspilia pluriseta		Ochna pulchra
	Laggera crispata		Pavetta schumanniana
	Asparagus aspergillus		Vangueriopsis lanciflora
			Rhus kirkii
			Psorospermum febrifugum

Tables 3a–3b: Dominant species composition for cultivated areas of the two main vlei types of Harare

Table 3a: Zone E Vlei land recently brought into cultivation

	Clay vlei	*Sandy vlei*
Grasses	***Perennial herbs/subshrubs***	***Grasses & sedges***
Hyparrhenia filipendula	Gnidia kraussiana	Bulbostylis hispidula
Brachiaria brizantha	Vernonia glabra	Cynodon dactylon
Melinis repens	Annona stenophylla	Heteropogon contortus
	Eriosema nutans	Pogonarthria squarrosa
	Aeschynomene mimosifolia	
		Herbs & shrubs
		Bothriocline laxa
		Richardia scabra
		Galinsoga parviflora
		Lannea edulis
		Maytenus senegalensis
		Lippia javanica
		Indigofera brachynema
		Psorospermum febrifugum
		Chamaecrista stricta

Table 3b: Zone F: Vlei land long since cultivated

Clay vlei	**Sandy vlei**
Common weeds	**Common weeds**
Acalypha crenata	Cynodon dactylon
Galinsoga parviflora	
Tagetes minuta	
Tridax procumbens	
Amaranthus thunbergii	
Bidens pilosa	
Nicandra physalodes	
Triumfetta annua	
Amaranthus hybridus	
Acalypha segetalis	
Hibiscus panduriformis	
Cyperus esculentus	
Ageratum conyzoides	
Tithonia rotundifolia	
Cynodon dactylon	

the parent material. Vlei vegetation is known to strongly reflect this pattern in the drainage conditions of the soil: a relatively small number of grass and sedge species able to withstand the seasonal waterlogging of the heavy-clay soils of the more central and potentially wetter areas of the vlei; a relatively small number of species tolerant only of dry conditions (often shrubs and trees) indicate higher land on the outer edges of the vlei; and a high species count (including a mixture of grasses, herbs, shrubs and the occasional tree) characterising the variable drainage conditions (both seasonally, from year to year, and spatially influenced, for example, by termite activity, microtopographic irregularities, or geological discontinuities) of the land in between.

To determine the effects of cultivation in these areas, it were thus important to undertake species presence-absence and abundance measurements of the vegetation sequence in transects across the vlei channel. This was done across the two main vlei types of Harare: the clay vleis of basic rock areas, and the sandy vleis of the granite rock areas. For both vlei types, species presence-absence and abundance data was recorded for areas of vlei where no cultivation has occurred, comparative areas of vlei heavily cultivated for at least several years, and comparative areas of vlei only recently brought into cultivation. From this information, the vegetation natural to both vlei types in Harare unaffected by cultivation can be determined.

In addition, the nature and intensity of the effect on the vegetation species and abundance present that the practice of cultivation in the vleis is having can be assessed.

The location of the seven main field areas are indicated in Figure 1. Area 1 (Borrowdale Park) and Area 3 (the Mukuvisi Woodland) provide information on cultivated and uncultivated vlei of fersiallitic soil (Soil Group 5, Thompson and Purves, 1978) developed from basic rock (largely dolerites and felsites): typical clay vlei. Area 4 (the Rolf Valley) and Area 7 (Meyrick Park) provide information on cultivated and uncultivated vlei of vertisolic soil (Soil Group 3, Thompson and Purves, 1978) developed from basic rock (largely felsites, with some influence of dolerites): also typical clay vlei. Area 2 (Cleveland Dam), Area 5 (Kutsaga) and Area 6 (Glen View) provide information on cultivated and uncultivated sites in areas of paraferrallitic soil (Soil Group 6, Thompson and Purves, 1978): typical sandy vlei developed from granite.

At each site, bands of vegetation parallel to the vlei channel were first determined by reconnaissance. The lower left hand corner of a measurement site to be representative of each identified condition (i.e. distinctive band of vegetation) was then located by pacing from the outer edge of the vegetation band using random number tables (stratified random sampling). Measurement sites were measured out at 10 m^2 and marked with tape. All plant species within each 10 m^2 site were identified (Drummond and Mapaure) and noted in groups of physiognomic type. The physiognomical distinctions used in the survey were as follows:

I) tall trees > 3 m; II) trees < 3 m; III) shrubs and herbs > 50 cm; IV) shrubs and herbs < 50 cm; V) grasses > 50 cm; VI) grasses < 50 cm (for the latter four categories also indicating whether weeds); and VII) crops. For each physiognomical type at each plot, the dominant species were noted and their abundance estimated. Percentage ground cover for the site was also calculated by visual assessment, using a 1 m^2 grid and percentage cover tables at ten locations within the site, determined by the random throwing of an object.

Research results

a) Detrended Correspondence Analysis

An ordination of the presence-absence species data for all sites was undertaken using Detrended Correspondence Analysis (DCA, Gauch, 1982; Ter Braak, 1988). This procedure gives a two-dimensional spatial plot of site numbers, the spatial proximity of each data point indicating the degree of correspondence in species present. Four broad groupings of data points (I, II, III and IV) are identified by this analysis on the data of this study (Figure 3). When the species composition of the groups of data points clustered by this analysis are examined, factors dominating species presence or absence become apparent.

Along DCA Axis 1 (the horizontal axis, Figure 3), group IV is completely separated from the other groups, and a small separation is also evident between groups I and III. The separation of the plots along this DCA Axis 1 appears to have determined moisture gradient as influenced by distance from the vlei channel. Plots from the drier parts of the vlei (furthest from the channel) are found on the left of the ordination diagram; plots closest to, or from within the vlei channel, are found to the right, with intermediates in between. This is determined to account for 70 % of the total variation in the species composition of the sites measured. Thus it is suggested there is a marked difference in species composition of the sites within these groups, reflecting moisture gradient, as determined by distance from the vlei channel. No significant difference between the species composition of sandy and clay vlei areas is found.

Along DCA Axis 2 (the vertical axis, Figure 3), group II is clearly separated from all the other groups. It is furthest from group I, and a similar distance from groups II and III. A small separation also exists between groups I and IV along this axis. These trends along this DCA Axis 2 seem to relate to

several factors. Apparent among them are the influence of cultivation, and vegetation physiognomy: Group III consists of vegetation of the cultivated areas, whilst Group II is the vegetation of the non-cultivated areas. The vlei channels, because of a big difference in their species composition, are found in between (Group IV). The two measurement sites in the woodland areas indicating the outer edge of the vleis (Group I) are clear of the other groups. Interestingly they are closer to the cultivated plots because of a number of weed species present (e.g. *Bidens pilosa, Bidens biternata* and *Tagetes minuta*) reflecting previous seasons of cultivation beneath the canopy. Again, no significant difference between the species composition of sandy and clay vlei areas was found.

Some level of intra-group variation is also apparent. Plots 12 and 25, for example, are situated in interesting positions within group III. These sites are vlei areas only recently used for cultivation. Plot 25 still has quite a lot of woodland species (such as *Ozoroa insignis, Protea gaguedi, Parinari curatellifolia, Senna singueana, Maytenus senegalensis* and *Lippia javanica*), hence it is placed close to the woodland plots (Group I). Plot 12 has a lot of species typical of non-cultivated vlei grassland (notably *Annona stenophylla, Gnidia kraussiana, Lannea edulis, Lactuca inermis* and *Vernonia glabra*), and hence is situated close to the rest of the dry vlei grassland plots (Group II).

Species Presence-Absence and Abundance of Dominants

The complete species presence-absence and abundance of dominants data obtained as a part of this study are being prepared for publication (forthcoming, 1996). Typical species composition within the two main vlei types of Harare are provided by this information, distinguishing the vegetation types of the vlei channels (Zone A); the areas adjacent to the vlei channels most frequently seasonally waterlogged (Zone B); the drier areas further from the vlei channel and sometimes affected by fire (Zone C); and where woodland begins on the outer drier edges of the vleis (Zone D). Within these vegetation types, the effects of recent and long standing cultivation is also documented (Zone E). A summary of the dominant species composition of these main vegetation zones follows.

The vegetation of the vlei channels (Zone A, and DCA Group IV) are characterised by species which can tolerate seasonal waterlogging and runoff flow. Dominant species of Zone A in the clay vlei areas include the grasses *Panicum trichonode, Eulalia aurea, Cymbopogon caesius, Hemarthria altissima, Eragrostis capensis, Leersia hexandra* and *Sorghastrum nudipes; and herbs Senecio inornatus, Alysicarpus zeyheri, Chlorophytum silvaticum, Commelina ceciliae* and *Ipomoea lapathifolia* (Area 1); and the grasses *Hemarthria altissima* and *Paspalum scrobiculatum* and herbs *Verbena bonariensis, Eriosema nutans* and *Senecio strictifolius* of Area 3. In Zone A of the sandy vlei areas, the grass *Hemarthria altissima* and sedge *Schoenoplectus corymbosus*, and the herb *Senecio strictifolius* dominate.

Vegetation just off the vlei channels (Zone B, and the data points to the right DCA Groups II and III) show a greater diversity of species type including species tolerant to waterlogging as well as others favouring drier conditions. Typical dominants of the clay vlei areas are the grasses *Brachiaria humidicola* with *Hyparrhenia nyassae*, also *Loudetia simplex, Eragrostis capensis*, and *Eragrostis hierniana* combined with a few broad-leaved herbs of which *Gerbera ambigua, Vernonia glabra* and *Oldenlandia herbacea* are prominent (Area 3); and the grasses *Imperata cylindrica* of Area 4. Typical dominants of the sandy vlei areas are *Arundinella nepalensis*, along with *Hyparrhenia rufa, Paspalum scrobiculatum, Digitaria monodactyla* and *Pennisetum macrurum* (Area 2).

Vegetation further from the channel (Zone C, and the data points to the left of DCA Groups II and III) shows a higher species diversity favouring drier conditions. Typical dominants of the clay vlei areas include the

grasses *Hyparrhenia filipendula, Themeda triandra* and *Hyparrhenia rufa* combined with small woody geophytic species (plants adapted to periodic fires which occasionally occur during the dry season through this zone), notably *Acalypha peduncularis, Scabiosa columbaria, Vernonia oligocephala, Becium angustifolium, Becium obovatum, Gnidia microcephala* and *Justicia elegantula* (Area 1); the dominant grass *Loudetia simplex*, along with broad-leaved herbs and sub-shrubs, notably *Tephrosia decora, Syzygium guineense* subsp. *huillense, Justicia elegantula, Eriosema shirense, Acanthospermum australe, Dicerocaryum senecioides* and *Acacia sieberiana* (Area 3); the grasses *Hyparrhenia filipendula* and *Cynodon dactylon*, and a wide variety of broad-leaved *perennial species*, most commonly *Acalypha peduncularis, Astripomoea malvacea, Convolvulus sagittatus, Helichrysum nudifolium, Eriosema ramosum, Eriosema nutans* and *Launaea nana*) of Area 4; and the grasses *Hemarthria altissima, Eulalia aurea, Hyparrhenia rufa* and *Cymbopogon caesius* of Area 7. Typical dominants of the sandy vlei areas include the grasses *Loudetia simplex* and *Aristida junciformis* of Area 2, and *Hyparrhenia filipendula*-dominated grassland with *Aspilia pluriseta, Becium angustifolium* and *Eriospermum abyssinicum* (broad leaved herbs) of Area 5.

Vegetation of the drier outer edges of the vlei (Zone D, and DCA Group I) notably includes trees (for example, *Bauhinia thonningii* and *Julbernardia globiflora* typical of clay vlei areas, and miombo woodland dominated by *Brachystegia spiciformis* typical of sandy vlei areas), and a significant number of shrubs and herbs (typical of clay vlei areas are the shrubs *Vangueriopsis lanciflora, Dolichos kilimandscharicus, Diospyros lycioides, Aspilia pluriseta, Laggera crispata, Asparagus aspergillus* and the grass *Digitaria milanjiana* of Area 3; typical of the sandy vlei areas are the shrubs *Ochna pulchra, Pavetta schumanniana, Vangueriopsis lanciflora, Rhus kirkii* and *Psorospermum febrifugum* of Area 2.

The effects of cultivation on the vegetation stands present are also clearly illustrated. Areas of clay vlei only recently brought into cultivation still have specimens of deeper rooted perennial herbs or subshrubs found in uncultivated areas. Notable species in this category are *Gnidia kraussiana, Vernonia glabra, Annona stenophylla, Eriosema nutans* and *Aeschynomene mimosifolia*; and the common grasses *Hyparrhenia filipendula, Brachiaria brizantha*, and *Melinis repens*. Typical of the sandy vlei areas, land only recently cultivated had a mixture of arable weeds and coppice saplings of the original woodland vegetation. The herb/shrub layer comprises a wide range of species including *Bothriocline laxa, Richardia scabra, Galinsoga parviflora, Lannea edulis, Maytenus senegalensis, Lippia javanica, Indigofera brachynema, Psorospermum febrifugum* and *Chamaecrista stricta*, among many others. Grasses and sedges are very few, of which *Bulbostylis hispidula, Cynodon dactylon, Heteropogon contortus* and *Pogonarthria squarrosa* are prominent.

Common weeds found in clay vlei areas cultivated for longer periods of time (at least four successive years) included *Acalypha crenata, Galinsoga parviflora, Tagetes minuta, Tridax procumbens, Amaranthus thunbergii, Bidens pilosa, Nicandra physalodes, Triumfetta annua, Amaranthus hybridus, Acalypha segetalis* and *Hibiscus panduriformis* (Area 1), *Cyperus esculentus, Galinsoga parviflora, Triumfetta annua, Ageratum conyzoides, Acalypha crenata and Acalypha segetalis* (Area 3), *Tithonia rotundifolia and Amaranthus hybridus* (Area 4), and *Cynodon dactylon* (Area 7). The dominant weed of sandy vlei areas cultivated for at least four successive years is *Cynodon dactylon* (notably Areas 2 and 6).

Photographs illustrating cultivated and uncultivated areas of vlei land in Harare are illustrated in Figure 4.

IV. Research findings

The results of this research reveal a marked distinction in species composition between

Typical uncultivated clay vlei area (Area 3: Mukuvisi Woodland) illustrating dry grassland (Zone C).

A view of vlei land in the dry season that has been used for cultivation in the preceding wet season

A new field recently prepared for cultivation in dry grassland area (Zone C) of a sandy vlei (Area 4: Cleveland Dam).

A weedy maize field with a poor crop affected by *Cynodon dactylon* and *Bidens pilosa*. Sandy vlei Area 6 at Glen View.

Figure 3: Photographs illustrating cultivated and non-cultivated vlei land in Harare

cultivated (DCA Group III) and non-cultivated (DCA Group II) vlei areas. This difference becomes greater the longer the vlei areas are under cultivation. The results also reveal how cultivation removes any difference in species composition with distance from the vlei channel.

The findings of this research thus clearly indicate how cultivation is resulting in alien arable weeds coming in to the area to replace the endemic vegetation. Every year of cultivation increases the loss of original species and their replacement by weedy communities. In the sandy vlei areas within Harare, which coincide with higher-density lower-income suburbs, and which have been subject to particularly widespread and intense cultivation for many years, a succession to a dominance by single weed species: *Cynodon dactylon*, is obvious. This species is commonly called couch grass in Zimabwe and elsewhere often Bermuda Grass.

Such effects of cultivation are thus characterised by a reduction of vegetation species diversity. With prolonged cultivation, only the vegetation stands of Group III on the DCA ordination diagram (Figure 3) will exist in the longer term (for example, if uncontrolled cultivation in the vleis of Harare is allowed to continue). Group IV will become choked by sediment eroded from the vlei drainage area because of the much-reduced ground cover and soil disturbance brought on by these cultivation activities. The trees of Group I will become increasingly obliterated as they get used as a source of firewood for Harare residents (as was observed during the fieldwork of this research). The remaining vegetation of these stands will be similar to Group III, once cultivated. Group II will successively alter in species composition, as illustrated by the data of this research, to resemble those of Group III.

Implication of the findings

There are considerable progressive effects for the entire vlei ecology resulting from this loss in biodiversity and percentage ground cover that has been illustrated by the results of the vegetation surveys presented in this paper. With more of the land surface exposed to the direct impact of rainfall and wind, it is expected that soil degradation (for example, an oxidation of organic matter content and a loss of soil structure), and soil loss by wind and water erosion, will occur (Bowyer-Bower and Tengbeh, 1995). The agro-potential of the land will decline accordingly (as described, for example, by Morgan 1986), and the vlei hydrology is also likely to alter. Serious potential effects include the choking of the vlei channels with sediment eroded from the vlei catchment areas as a result of cultivation (and giving rise to an appearance of the vleis having dried); and increased ëpeakednessí in storm runoff in areas where soils become crusted by cultivation, which gives rise to intermittent flooding (of considerable nuisance to an urban area) rather than steady channel flow (Bowyer-Bower and Tengbeh, 1995).

With fewer of the taller vegetation species natural to vleis surviving the cultivation activities, a further implication is that there is less cover and camouflage for larger species of wildlife, which are thus now rarely found in the Harare vleis. A reduction in the number of species of both fauna and flora in many areas of Harare's open spaces, has meant that the survivors are increasingly confined to a few remnant protected land areas within Harare. One such refuge is the newly established Haka Game Reserve in a part of the

Cleveland catchment area (a sandy vlei on granite). A second is the Mukuvisi Woodland (intermediate between clay vlei and sandy vlei, at the junction between several rock types), which is a nature conservation area protected from human disturbance and urban development, and needs careful management to prevent a decline in species diversity caused by the introduction of too large a population of herbivores.

The importance of such refuges for retaining ecological diversity in Harare, particularly at a time of escalating urban development (both planned and unplanned), and the value of their informed and careful management, is thus clearly illustrated by the research presented in this paper. Whilst it is recognised that the apparent needs of the urban poor to have access to land for cultivation to supplement their household provision cannot be ignored (Bowyer-Bower, 1996b), it is suggested that the need for a more careful management regime of further open vlei areas in Harare, whilst the option of their conservation as areas of viable natural ecological diversity is still available, should also be considered.

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